Virtual Reality Technology Applied in Teaching and Research in Civil Engineering Education

Alcinia Z. Sampaio [*1]

Department of Civil Engineering and Architecture, Higher Technical Institute, Technical University of Lisbon Av. Rovisco Pais 1049-001 Lisbon, Portugal

[*1]zita@civil.ist.utl.pt

Abstract

Besides the constant updating of training in the new graphic resources available to engineering and architecture professions, and in widespread and frequent use, the school should also adapt its teaching activities to the new tools of visual communication. In Civil Engineering, the capacity to visualise the construction, management and maintenance of buildings can be added through the use of three-dimensional (3D) models which, facilitate the interpretation and understanding of target elements of maintenance and construction and of 4D models (3D + time) through which the evolution of construction steps and deterioration of materials can be visually demonstrated and understood. Furthermore, the possibility of interaction with the geometric models can be provided through the use of Virtual Technology (VR). The text presents diverse perspectives of introduction a new technology in school. It can be used as a tool to create didactic applications and as a new issue in the training of students. The students involved, in the research works had to learn advanced software of geometric modelling and visualization and to explore the capacities of a VR technology system. Also programming skills had to be adapted to establish the integration needed for the creation of virtual prototypes. Furthermore, the structure of different kind of databases had to be studied and implemented, integrating diverse type of information, needed to develop the interactive virtual model. The VR technology was introduced in school in order to prepare civil engineering students to consider this knowledge as an important support, later in professional activity, and also to facilitate the link between, engineering theory and its implementation.

Keywords

Education Research; Technology in Education; Virtual Reality; Engineering Education

Introduction

Today, several type of software is used in practical discipline in engineering, which requires that future engineers have the competencies and knowledge to develop economical and feasible solutions. An engineering school can be expected to constantly update computational resources which are in frequent use in the professions. The introduction of new technologies in the designers practice has been everything but smooth (Matejovska and Achten, 2011). Undergraduate students must be educated and trained to perform the roles required for software development in order to create effective solutions. Time and experience permit problem categorizing, so the contact of engineering students with new technologies in the early stages of their learning and training process is important. The teacher is the responsible educator of creating an educational environment, such as it is the case for the creation of a self-study or practice. It is necessary that the educator find and use resources supporting different issues in civil engineering field. Resources should be introduced into the training of the student, leading to their adaptation for curricula in drawing and geometric modelling disciplines.

Computer-Aided Design (CAD) techniques can produce educational materials, likely to be used for training of future researchers and professionals in engineering subject. In addition, the interaction with the VR models helps student to better understand the diversity of the engineer activity. A reliable identification of motivational factors would usefully inform pedagogical interventions (Savage et al., 2012). And students who are more intrinsically motivated may benefit of the possibility of interacting with the model. Practice and training in virtual worlds are important factors to achieve the required level of competencies and collaboration between academy and

industry can generate proper scenarios for real practices. Applications like virtual training environments, virtual prototyping of designs, and joint virtual development of information systems require a valid representation of the real environment. Often, the real environments are building facilities such as construction, management and maintenance. The aim is to achieve a complete analysis of reality through including the perspectives of experts in several areas of knowledge. It is the way to attain a fully defined reality. The processes and results achieved in situ tasks and the subsequent analysis will create the ideal resources for incorporation into educational tasks. Thus, it is possible to train new researchers and professionals in the engineering activity.

Advantages of 3D virtual environments are found in improving communication, increasing insight, supporting collaboration, and supporting decision-making (Fumarola and Poelman, 2011). The divergence in 3D virtual applications requires different type of requisites of the real environment. This can be illustrated by the different VR models developed, and presented in this text, to motorize the construction or maintenance activity or for educational propose, both in the Civil Engineering domain. The author has been supervising the development of several applications in different branches of knowledge which have been successfully implemented (Sampaio, 2011). This text intends essentially to highlight the new possibilities that the use of VR could bring to engineering education to support class-based learning and in research works and after on the activity of the students as professionals. VR technologies were applied on the development of didactic models in Civil Engineering domain and on the implementation of research applications:

- The 3D models created to support rehabilitation projects helps to outcome the building anomalies and to evaluate different alternative of rehabilitation solutions. The models were created by students as study cases;

- The main objective of the practical application of the didactic models concerning construction processes is to support class-based learning and in distance learning using e-learning technology. The models presented the

construction of a roof and bridge decks using two different methods;

- The applications regarding the management of buildings were developed within a research project (Sampaio and Gomes, 2011). The implemented virtual prototypes concern the management of a lighting system in a building, the construction activity and the maintenance of building components.

3D and 4D virtual environments

There is an increase in use of 3D virtual environments in architecture, engineering, and construction (AEC) industries (Fumarola and Poelman, 2011). Frequently, the design drawings are complex, show different layers, steps or details, and therefore become hard to understand. The 3D visualization can be used as a platform for shared understanding to be used by every participant involved in the design process. For the presentation of the final result to stakeholders, a 3D visualization with a reduced level of complexity is preferred. For the geometric description are employed graphics techniques like CAD. The different types of visualizations, both in 2D and 3D, achieve different types of fidelity for each specific goal.

Virtual environments can be especially valuable where training in real-world situations would be impractical because a real field scenario may be unduly expensive, logistically difficult, dangerous, or too difficult to control. Compelling virtual environments could lead human participants to feel somehow present, for purposes of training. Part of the components involved in the interactive virtual training environment are simulated, the operator nevertheless can experience a similar sense of being present and interacting with real/virtual objects via visual. Virtual environments can assist with the use of equipment operation training and novices have much more time to practice their skills without the pressure of costs.

Construction project planning has been considered as a critical process in the early project phases that determines the successful implementation and delivery of project (Huang et al., 2007). During this stage, project planners need to develop main construction strategies, to establish construction path and assembly sequences, and to arrange construction methods and resources required for the execution of work packages. Such shortcomings of traditional

communication tools together with the advances in digital technologies have stimulated various research and development efforts to develop new innovative construction process planning techniques in order to enhance the visualization of the construction sequence and finished product. The latest research development relates to the development of graphical presentation of construction plan via the four-dimensional (4D) geometric models (i.e. 4D-Planner). A 4D CAD model is generated from the combination of 3D graphic images and the time. The 4D visualization technique provides an effective means for communicating temporal and spatial information to project participants. Finished projects are visualized and spatial configurations directly shown. Visualization of construction plans allows the project team to be more creative in providing and testing solutions by means of viewing the simulated time-lapse representation of corresponding construction sequences.

Rehabilitation 3D models

The 3D modelling is a very important tool to support rehabilitation decisions. In both analysed cases, the 3D models were created in order to survey the anomalies in the structures and to support decisions based on the visual analyses of alternative solutions of rehabilitation (FIG. 1): J. Neves (Sampaio et al. 2010) studied an historic building that was submitted to a rehabilitation process that includes the detection of structural anomalies, the replacement of damaged resistant elements and the adaptation of the building to new services and the 3D model allowed a quicker understanding of the structural organization of the building and it was a useful tool for the surveying and mapping of its damages; Bruno M. (Martins, 2008) considered the installation of new sanitary equipment in an old building, which presents a significant degree of degradation and two alterative solutions were workout and modelled assisting the analyses of the space, in an aesthetic point of view, to identify incompatibilities and to carry out information (specification of sanitary elements, the quantity of pipe elements and the characterization of covering materials of walls and floor).

Both cases are student works. These works are a contribution to the acceptance of the use of CAD, not only as a good "drawer", but also as an important support on the analyses of rehabilitation works. Thus, teaching CAD in school is helpful to students in order

to prepare them to consider this technology as an important support, later in professional activity.
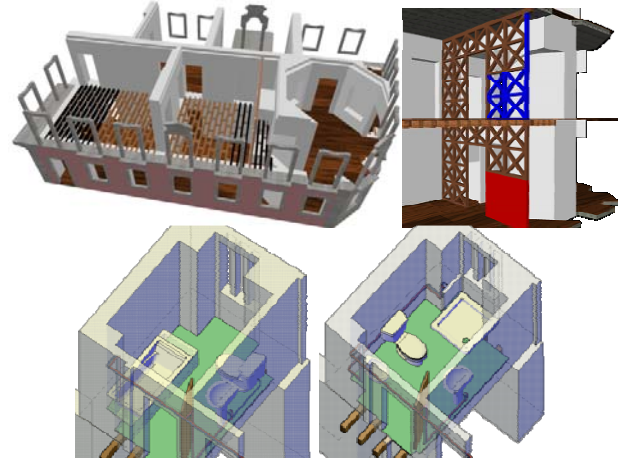

FIG. 1 THE REHABILITATION 3D MODELS.

VR didactic applications

The virtual models can be very useful both in face-to-face classes and in distance learning using e-learning technology. VR provides opportunities to deliver technical education in ways not possible through traditional methods, thereby broadening the range of tools available to modern educators, in order to reach more students and subjects. A didactic application to be used as an e-learning tool must meet the following requirements: reusability, accessibility, durability and interoperability (Birzina et al., 2012). Thus, it seeks the same educational database for be used by the international community through different learning software. Furthermore, it is necessary employ an accepted format with the aim of facilitate communication between different databases of several areas of knowledge. Also another important point to be considered is those models in e-learning institutions should be independent of country, language or any other regional circumstances in the process of creation the didactic models.

The use of the EON software (EON, 2011), a system of virtual reality technologies, on the development of the didactic models presented in the text, which can be free downloaded, enables the VR application to be used for a multitude of handlers. For that, the user should download the EON Viewer application available at: http://download.eonreality.com. Through direct interaction with the models, it is possible both to monitor the progress of the construction process of the roof and bridges and to access information relating to each component of the educational model. Different

didactic applications have been implemented to explore the benefits of 3D virtual training in drawing and construction issues. The objective is not to replace current training methods but to position accurate as an additional teaching method. To do so, there were developed immersive 3D models that were based on an actual method of teaching.

Roof VR model

An educational model related to the graphic construction of a roof drawing was created (Sampaio and Cruz, 2011). The graphical definition of a roof requires a geometric description which results in the generation of a 3D model. This process can be carried out mainly through surface modelling that consists to obtain the model shape through using polygonal meshes (plan surfaces). The representation systems normally used are basically two: (1) Orthographic projection: it is a parallel and orthogonal projection system. The projection is done on two planes perpendicular among themselves. This way allows to measure directly. It is used in 2D representations; (2) Axonometric system: is a parallel projection and orthogonal over a tri-rectangle trihedral. It is employed in 3D representations. The VR model helps to better understand both projections modes.

When defining 2D and 3D models some geometric elements must be used: the slopes represented by their corresponding right-angled triangles and the elevation lines. These are shown traced on a plan but they identify 3D elements. In order to facilitate the ability to understand the spatial aspect inherent in the process, a didactic model was created in which all the methodology underlying its construction is presented in a virtual interactive environment (FIG. 2).
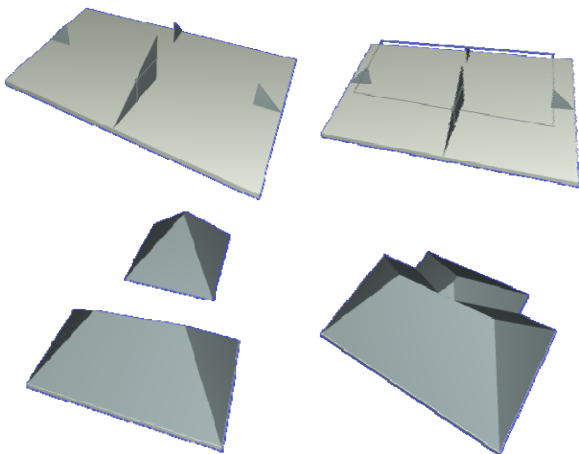

FIG. 2 ANIMATION SEQUENCE OF THE ROOF CONSTRUCTION.

The model allows interaction with the roof modelling process sequence enabling the user to backtrack and manipulate the camera position and distance in relation to the model. The final objective of this model is to show the complete roof constructed on a basis of the concepts of engineering drawing applied to the plan drawing of that structure. The intersection of the two blocks of the roof clearly illustrates how roofs with more than four planes must be executed.

Bridge deck VR models

The bridge models allow the visual simulation of the construction of a bridge using two different construction methods: the cantilever process (Studer and Sampaio, 2004) and the incremental launching method (Martins and Sampaio, 2009). The support of specialist in bridge designs was essential to obtain accurate models, not only on the geometry definition of components of the bridge and devices, but also on the establishment of the progression sequence and of the way the equipment operates. Students are able to interact with the models dictating the rhythm of the process, which allows them to observe details of the advanced equipment and of the elements of the bridge (pillars, deck and abutments). Every elements needed in the virtual scenario were modelled using AutoCAD and then the interaction was programmed using the VR-based software, the EON Studio.

The sequence is defined according to the norms of planning in this type of works: the cantilever method starts by installing on a first segment on each pillar the work equipment and the construction of the deck proceeds with the symmetrical execution of the segments starting from each pillar, using the advanced equipment; it is completed with the positioning of the closing segment and; finally the zone of the deck near the supports is constructed, using a false work resting on the ground (FIG. 3).

The incremental launching method consists of casting 15m to 30m long segments of the bridge deck in a stationary formwork to push a completed segment forward with hydraulic jacks along the bridge axis. The VR model concerning construction of deck bridges using the method on incremental launching provides a contribution to the dissemination of information concerning this construction method, through a recording of visual simulation of the phases and the equipment that comprises the construction process.
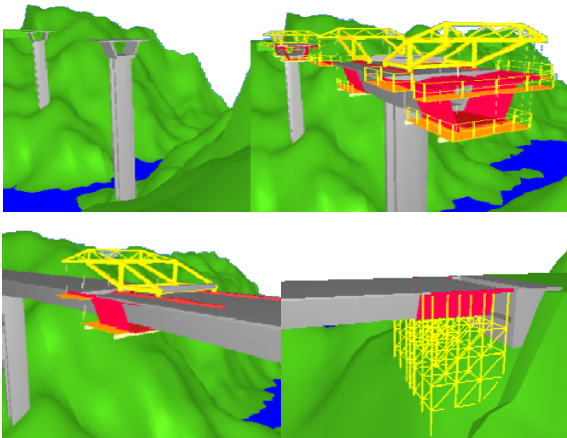
FIG. 3 ANIMATION SEQUENCE OF THE CANTILEVER METHOD OF THE DECK BRIDGE CONSTRUCTION.

The VR model allows the interaction with the construction sequence (FIG. 4): At the casting yard the external panels of the shuttering and the reinforcement mesh were placed, and then starts the visual simulation of the casting work; the assembly of the launching nose is installed and the displacement of first segment of the deck takes place; the arrival of the nose to the first pier is achieved during the advance of the second segment and the camera is positioned to show properly the work; the construction of the remaining segments is performed and already in the final phase of construction, the nose arrives at the abutment, the yard is removed and the space is covered of land; finally the guards are positioned and also other finishing elements.
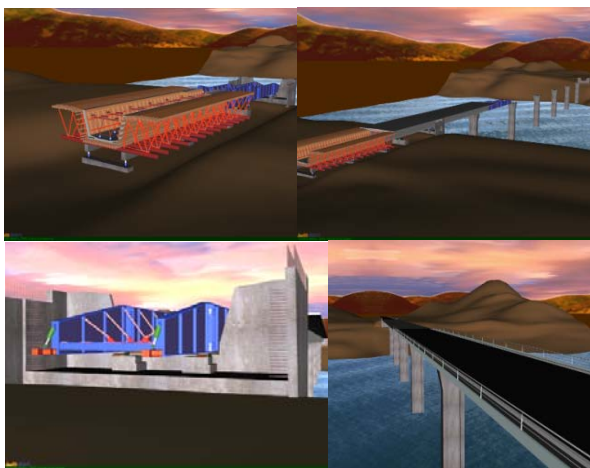

FIG. 4 ANIMATION SEQUENCE OF THE INCREMENTAL LAUNCHING METHOD OF DECK BRIDGE CONSTRUCTION.

These models present a great complexity of geometry and material concerning the different elements used in a real work process and they provide an immersive capacity inherent to virtual world. They were programmed in order to show correctly both

sequences and they illustrate in detail the movement of the equipment. In class, the teacher must explain way the process must follow that sequence of steps and the way the equipment devices operates. The student, interacting with the virtual model, can follow the sequence specifications and observe the details of the configurations of the elements involved. In a real construction place of a bridge, for security reasons, the student stays far from the local were bridge is under construction, so they cannot observe in detail the way of operation and the progression of the construction. When the student goes to a real work place he can observe the complexity of the work and better understand the progression of construction previously explained and observed in the VR model.

Research project

The main aim of a research project (Sampaio and Gomes, 2011), developed at the Department of Civil Engineering of the Technical University of Lisbon (TU Lisbon), was to implement virtual models as tools to support decision-making in the planning of building management and maintenance. A first prototype concerning the lighting system was developed (Sampaio and Ferreira, 2010). A second prototype regarding the construction of a building and the related sequence of activities was also created (Santos, 2010). Two VR models supporting the maintenance of the closure of walls, both interior walls (Rosário, 2011) and façades (Gomes, 2010), has already been completed.

Utilizing information technology in the construction industry has been an issue of great importance in order to enhance the effectiveness of construction projects throughout their life cycle and across different construction business functions (Hartmann and Levitt, 2010). In addition, a good visual representation of data can assist people in efficiently acquiring applicable information: 3D visualization (displays 3D models of the building); 4D visualization (displays various 3D models incrementally at the various stages of construction activities as construction progresses over time); and nD visualization (shows the integrated data after data binding) (Wua and Hsiehb, 2012). Using visualization expands the usability of data, information and knowledge following universal laws that are unavoidable and undisputable but can be learned and taught. 4D modelling (3D+time) and VR technics has been used in the construction activity. In

fact, VR is one of the important areas in current research namely on technological development and on its application and adoption by the practices (Kerry, 2010). Visualization can share the intent to communicate and re-construct meaning. Representation of knowledge visualization benefits from cognitive sciences' experimentation within the field of expertise and qualitative reasoning. The knowledge visualization is presented when interacting with the VR applications. The information presented changes with the time factor (4D model) and in an interactive way shown through the interfaces developed for the VR applications.

VR lighting system

The prototype regarding the lighting system uses an interactive 3D visualization system based on the selection of element directly within the virtual 3D world and associated with each component there are integrated databases, allowing the consult of the corresponding technical information concerned with the wear and tear aspects of the material, in any point in time. So, the prototype links the 4D model to a data base about the lighting system management within a collaborative virtual environment (FIG. 5).
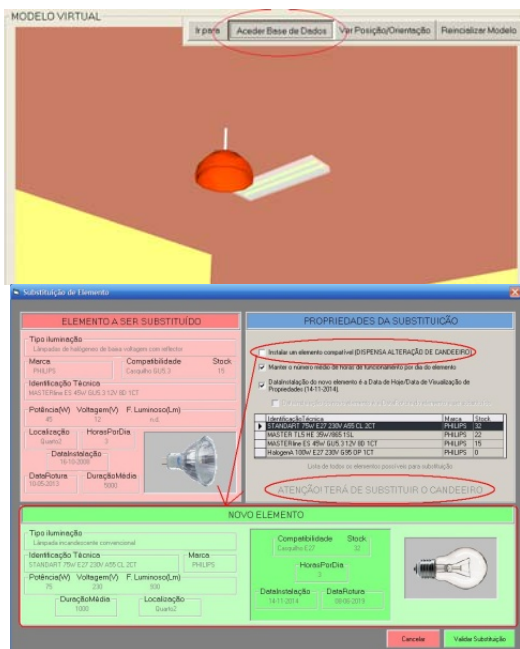

FIG. 5 LIGHTING SYSTEM VR MODEL.

The scholarships holders involved, in this work, are 5th year students of Civil Engineering. They had to learn advanced software of geometric modelling and visualization and to explore the capacities of a VR technology system. Also programming skills had to be

adapted to establish the integration needed for the creation of a lighting virtual prototype. Furthermore, the structure of different kind of databases had to be studied and implemented, integrating diverse type of information, needed to develop the interactive virtual model.

Construction VR application

Construction progress monitoring has been recognized as one of the key elements that lead to the success of a construction project (Son and Kim, 2010). By performing construction progress monitoring, corrective measures and other appropriate actions can be taken in a timely manner, thereby enabling the actual performance to be as close as possible to the desired outcome even if the construction performance significantly deviates from the original plan. However, current methods of data acquisition and its use in construction progress monitoring have tended to be manual and time consuming. The complicated nature of construction works makes the detailed progress monitoring challenging. Current construction progress monitoring methods involve submission of periodic reports and are constrained by their reliance on manually intensive processes and limited support for recording visual information.

Recent advances in image-based visualization techniques enable reporting construction progress using interactive and visual approaches (Roh at al., 2011). In order to ensure effective monitoring and control of construction projects, owners and project stakeholders often require detailed construction reports and traditionally, they are paper-based daily progress reports. In recent years, web-based technologies have also been used to automate paper-based processes but it can be used to exchange actualized information between partners (Rezazadeh et al., 2011). The proposed VR performance can provide critical information in monitoring and control of construction progress and costs, or in decision making. Thus, for effective monitoring construction works, it is important to provide additional processes to better understand the link between the subcontractors' activities and schedule with spatial contexts from 2D drawing or 3D model and, as an innovative use, the VR technology.

In the construction industry, some progress has been achieved by researchers to design and implement

environments for task training using VR technology. The VR application proposes an efficient, automated 3D structural construction components follow a Gantt map and photos acquired from the construction work place, for use in construction progress monitoring. An outdoor experiment was performed on an actual construction site to demonstrate the applicability of the method to 4D/VR modelling of such environments, and the results indicate that the proposed method can be beneficial for construction progress monitoring. This research focuses on visualization based on photos and VR techniques to monitor detailed construction progress. Several as-built photographs can be visualized and compared in a walk-through interactive model. This application introduces an advanced model that enables the user to have a realistic understanding of the construction progress.

The prototype based on VR technology with application to construction planning, presents the project in a 3D way, connected to construction planning schedule, resulting in a valuable asset in monitoring the development of the construction activity, based on the construction planning designed (FIG. 6).
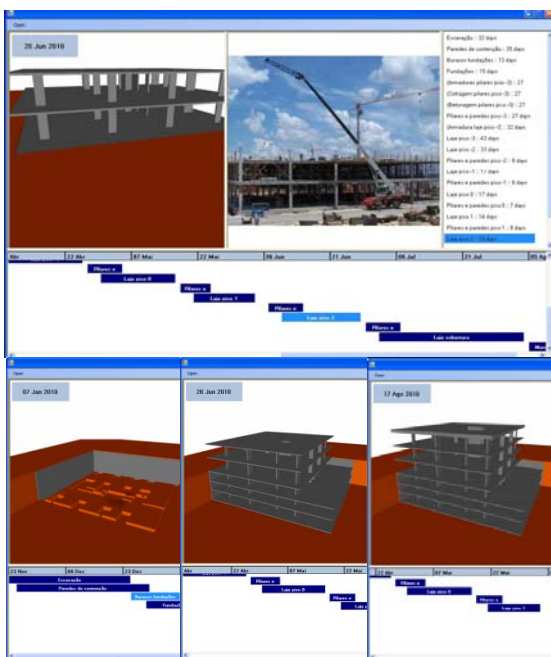

FIG. 6 CONSTRUCTION VR MODEL.

The 4D application considers the time factor showing the 3D geometry of the distinct steps of the construction activity, according to the plan establish to the construction. The 4D model offers a detailed analysis of the construction project. The proposed system will make 4D models more complete by adding temporary works and their activities to set them and dismantle them. It will aid planners to review the construction process planning and analyse the work space layout more efficiently.VR technology is used and presented as an innovative visual tool. It allows the visualization of different stages of the construction and the interaction with the construction activity. This application clearly shows the constructive process, avoiding inaccuracies and building errors, and so improving the communication between partners in the construction process. This tool is an important support in project conception and application.

The student Joana has acquired several skills in order to define this VR model during the research work within a Bologna thesis. The skills learned are related to programming, with knowledge regarding the constructive process and with the use of a VR-based. The application was developed in three stages: the planning, using Microsoft Project 2007, considers the definition of the tasks and the relations between them defined; the geometric modelling related to the tasks defined in the planning stage and each element was created considering the detail necessary to the correct comprehension of the construction process; the third stage, the integration, makes use of the software EON Studio and Microsoft Visual C#, where the first takes the 3D model and introduces it in the application developed using the second. This prototype's weakness is the time needed to make the preparation for the actual interaction with the application. Modelling the structure of the building was not much extended; however, the programming of the actions in EON Studio was time-consuming.

Maintenance VR application

In a building, the coatings applied to walls convey their aesthetic character and also performs an important function of protection. It is a construction component which is exposed to agents of deterioration related to its use, needing the regular evaluation of its state of repair. The walls have a continuous lifestyle, so they requires the study of preventive maintenance (the planning of periodical local inspections) and of corrective maintenance with repair activity analysis.

The developed maintenance models allow interaction with the 3D model of a building, visualizing updated information related to the covering materials of the walls. It allows the visual and interactive transmission

of information related to the physical behaviour of the elements, defined as a function of the time variable. The models are linked to specific database of the corresponding technical information concerned with the maintenance of the materials used as exterior closures (Gomes, 2010) and interior finishes (Rosario, 2011).

The visualization of the maintenance data of a building and the impact of time on the performance of these exterior closure materials require an understanding of their characteristics. The most frequent materials used as coating finishes are painting, tiling and, as sealing coating of the natural stone. In order to better understand the operation of façade coating, bibliographic research of materials usually applied to façade coatings was carried out and a table of characteristics of these was drawn up. This includes a survey of anomalies, probable causes, solutions and methods of repair for each of the coatings studied. This information was included in a data base that supports the periodic inspection needed in a program of preventive maintenance. The results are obtained interactively and visualized in the virtual environment itself (FIG. 7).
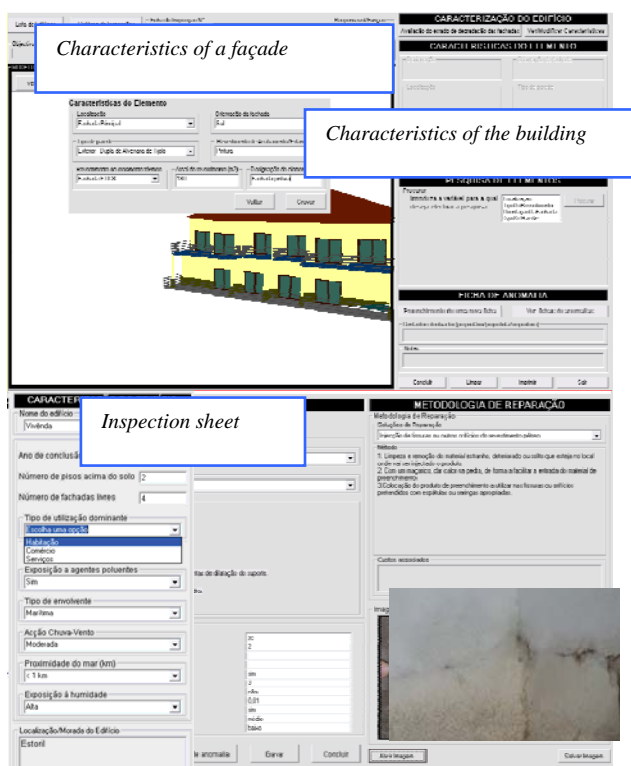

FIG. 7 VR MODEL OF FAÇADES MAINTENANCE.

The second VR model supports the performance of periodic inspections and the monitoring of interior wall maintenance (FIG. 8). Used during an inspection visit, the application allows users to consult a database of irregularities, normally associated with paint coating, classified by the most probable causes and by recommended repair methodologies.
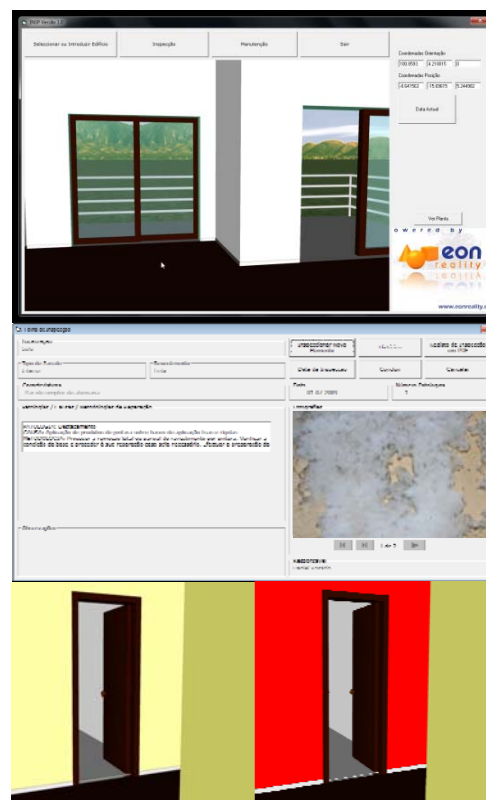

FIG. 8 VR MODEL OF PAINTED INTERIOR WALLS MAINTENANCE.

In addition, with this model, a chromatic scale related to the degree of deterioration of the coating, defined as a function of the time between the dates of the application of the paint and the scheduled repainting, is attributed to each element of coating monitored. This use of VR technology allows inspections and the evaluation of the degree of wear and tear of materials to be carried out in a highly direct and intuitive manner.

The prototypes were trailed in a concrete project. This work brings an innovative contribution to the field of maintenance supported by emergent technology. The principal objective of the interactive VR prototype is to support the maintenance management of buildings.

The present prototypes use an interactive 3D visualization system based on the selection of elements directly within the virtual 3D world. They incorporate interactive techniques and input devices to perform visual exploration tasks. Human perceptual and cognitive capabilities were taken into account when designing this visualization tool so the

model is easy to use and does not require sophisticated computer skills (many potential users are not computer experts). The implementation of the VR systems makes use of graphical software programming, Visual Basic, software to establish an adequate database, Microsoft office access, graphical drawing system, AutoCAD and VR technology based software, EON Studio. The programming skills of the students involved in the project had to be enhanced so that they could achieve the integration of the different kinds of data bases needed in the creation of the interactive model.

In the second model, the period of time between the date indicated and the date when the paint was applied is compared to the duration advised, in the technical literature, for repainting. The value given for this comparison is associated to the Red, Green, Blue (RGB) parameters which define the colour used for wall in the virtual model. In this way, the colour visualised on the monitored wall varies according to the period of time calculated, pale green being the colour referring to the date of painting and red indicating that the date the model was consulted coincides with that advised for repainting (FIG. 8). The student had to learn Computer Graphic issues in order to programme in the EON system the changes of colour of the elements of the walls.

Educational aspects

Didactic models, referred in item IV, are used in classrooms and web platforms. In face-to-face classes the teacher uses the models as a support to the introduction of new subjects. The 3D model/RV concerning each constructive process is presented in a sequential and animated manner, controlled interactively by the professor. The model can support properly the explanation for each construction step. The model has advantages in the activity of teaching by allowing the visualization of the physical evolution of the construction process and the most adequate zoom in order to observe the geometric details of each component. The teacher interacts with the models at a speed that is most convenient for the description of each issue.

The didactic models are actually used in face-to-face classes of disciplines of Civil Engineering curriculum: Technical Drawing (1st year), Construction Process (4th year) and Bridges (5th year). The teacher interacts with the model showing the sequence construction and the constitution of the modelled building element.

As in Technical Drawing, students have to define and represent roofs using 2D drawings; they better understand the relations between the 3D graphical elements used in 2D representation, following the exhibition of the VR roof model. In Construction Process and Bridges, in order to prepare students to visit real work places, the teacher shows the construction animation and explains some aspects of the construction process that in the work place they are going to see. The deck bridges models particularly show the complexity associated to the construction work of the deck and illustrate in detail the movement of the equipment. In class, the teacher must explain way the process must follow both sequence of steps and the way the equipment devices operates. When the student, of the 5th year, goes to a real work site he can observe the complexity of the work and better understand the progression of construction previously explained.

The students reflected on their evaluation works a better understanding of subjects concerning structures and construction. For instance, when the students went to a work place they objective more there attention to some kind of details and sequence of working presented in the models. Teachers realized that the students' reports of visits to work places included now some aspects shown in the virtual models and they are more detailed. So, these models are beneficial to students.

When the VR models are placed on the web pages of their respective disciplines, the student has free access to the model and can observe the constructive process ahead or kicking steps and visualize, with the most appropriate point of view and zoom, the geometric detail of some elements or interconnection mode between the various components of the building. The models presented in the classroom, or through a web platform can provide additional means. Both situations are currently used in teaching Construction discipline of the Civil Engineering Department.

The models relating to the construction and maintenance of buildings (item V) constitute part of the research project, of which the author is the principal investigator, and also they are part of Bologna thesis. So they are part of the curriculum of the Master in Civil Engineering. Teaching and

research are complementary in these works. Students gain skills to use VR-based software that can be used later in his activity.

Conclusions

An engineering school can be expected to constantly update computational resources which are in frequent use in the professions. Civil Engineering students were educated and trained to perform the roles required for software development in order to create effective solutions. Time and experience permit better resolution of problems, so the contact of engineering students with new technologies in the early stages of their learning and training process is important. It is necessary that the educator can find and use resources supporting different issues in Civil Engineering field. Resources should be introduced into the training of the student, leading to their adaptation for curricula in drawing and geometric modelling disciplines. The author as a teacher has been supervising educational environments, such as it is the case for the creation of a self-study or practice.

CAD and VR techniques were applied on the production of educational materials and on research works within Bologna thesis. The interaction with the VR didactic models helps student to better understand the diversity of the engineer activity. Practice and training in virtual worlds are important factors to achieve the required level of competencies and collaboration between academy and industry can generate proper scenarios for real practices. Applications like virtual training environments and virtual prototyping of planning construction and management were created. The aim of the research works was essentially to provide students skills and expertizes in several areas of knowledge using an emergent information technology.

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Alcínia Z. Sampaio, Assistant Professor at the Technical University of Lisbon (TU Lisbon), in the Department of Civil Engineering, PhD in Civil Engineering by TU Lisbon, since 1999, MSc in Structures Engineering by TU Lisbon, since 1989, and BSc in Civil Engineering by TU Lisbon, since 1983.

She teaches Technical Drawing since 1984 and Computer Added Drawing since 2003 for Civil Engineering students. She has organized short courses in Nov. 2010, Introduction to Virtual Reality Technology applied on architecture and Engineering, TU Lisbon and in Feb. 2009, Automatic generation of drawing using DXF files, TU Lisbon.

The main research fields are Geometric modeling and virtual reality applied to construction. She is member of Institute of Construction at the TU Lisbon. She has supervised the researcher project Automatically Generating Model of Bridges Graphic Representation, (2001-2004) and has collaborated with the projects Virtual reality in optimization of construction project planning, (2001-2004). Also has developed didactic models to support engineering education recently she was the principal researcher of the project Virtual Reality Technology applied as a support tool to the planning of construction maintenance, (2008-2011). A new research project is in progress Maintenance of Buildings supported on BIM (Building Information Modelling) Technology (2012-2014).

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